Chapter 3

3 Introduction

3.1 Jet Reconstruction

To reconstruct jets in the detector, a cone-based algorithm is used. It begins by selecting preclusters made of towers in the calorimeter with a transverse energy(E_T) greater than 1.0 GeV, where the highest tower is located near the center of the cluster. Each precluster is limited in size with a maximum ϕ of 105° and maximum η of 0.7 units. These limits correspond to a maximum cluster size of 7x7 towers in the central calorimeter and 21x7 towers in the forward and plug regions. Clusters are made by finding the E_T weighted centroid of the preclusters forming cones in the $\phi - \eta$ plane with a fixed radius of $R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$. If a tower is inside the radius of the cone and has an $E_T > 100 MeV$, it is included in the cluster. Then the E_T weighted centroid of the new cluster is recalculated and this process is repeated until the tower assignment to all the clusters remains constant. If overlap of towers occurs between clusters, further redistribution is required. It has been found through Dijet studies that the optimal cone size is in the rage $0.4 < R < 1.0$. A cone size of 0.4 is used in this analysis and if also the most common choice throughout the experiment.

3.2 Standard Jet Energy Corrections

The jet energy as measured by the detector's calorimetry needs to be corrected due to a number of detector and physics effects. Historically, there have been eight levels of corrections which, depending on the analysis, will be employed in combination. This analysis uses levels one, four, and five to correct the jet energies. Levels two, three, and eight have become obsolete and are no longer used. Levels six and seven are only used if a particular analysis calls for them.

3.2.1 Level 1 Relative Energy Correction

The relative energy correction is also known as the η-dependent correction. It is the first correction that needs to be done and makes the detector's response as a function of η uniform. In a $2 \rightarrow 2$ process the E_T of the jets should be equal. This is used to scale the jets outside

the $0.2 < |\eta| < 0.6$ region to the jets inside this region. The region corresponds to the central calorimeter away from the cracks, which is the best understood calorimeter in the detector.

3.2.2 Level 2 Central Calorimeter Stability

As the detector ages, the energy response of the calorimeters changes. This correction is dependent on the time period in which the data was taken, and is applied on a run by run basis. This level is no longer in use and it's correction is taken into account in the energy scale calibration.

3.2.3 Level 3 Scale Correction

The level 3 correction is a scale factor that relates the old Run I absolute energy corrections to the current ones, and allow the old absolute corrections to be used. It is important to verify that the linearity of the detector has not changed since Run I. An ADC-to-GeV scale factor is downloaded to the hardware on a tower by tower basis and used online in the L1 and L2 triggers. The same scale factor is used in L3 and offline. Next, the CEM and CHA scales have to be checked so that an offline correction can be applied if needed. To set the CEM scale factor $Z^0 \rightarrow e^+e^-$ are reconstructed so that the Z^0 mass is

$$Z^0 = 91.05 \pm 0.29 GeV \tag{1}$$

The scale factors need to be updated periodically as the CEM ages.

The CHA energy scale is set with the minimum ionizing particle(MIP) peak of low and high P_T muons. The jet energy scale is check by using photon-jet balancing, since the CEM can measure photon energy very precisely. Essentially, once the scales for the CEM and CHA are set, photon-jet energies from RUN II can be compared to Run I and should be identical.

This level is also no longer used since the experiment has a new Run II absolute energy correction, making this scale factor obsolete.

3.2.4 Level 4 Multiple Interactions Correction

Given the current luminosity of the proton anti-proton beams and its thirty-six bunches, it is likely that an event will overlap with an additional minimum bias event. This is where there

is more than one collision in the same beam crossing. Energy from particles in this extra event may fall in the cone of the jets from the primary event. This energy needs to be subtracted from the cone before analysis. The correction is parameterized in terms of additional energy per number of vertices in the event. Additionally, this correction is assigned an uncertainty of 100 MeV/vertex.

The following table shows the additional energy per vertex that was calculated in both Run I and Run II.

GeV	Cone 0.4	Cone 0.7	Cone 1.0
Run I	0.297	0.910	1.858
Run II	0.260	0.781	1.581

3.2.5 Level 5 Absolute Energy Correction

After correcting for any non-linear response from the calorimeter in the un-instrumented regions, the jet energies may still be incorrect. For historical reasons, a 50GeV pion was used as a calibration point. The energy deposited by this pion may not be calibrated to 50GeV, so a correction in the data is required. This correction is called the Absolute Energy Correction. It depends on the jet fragmentation properties, the non-linearity of the calorimeter, the difference in calorimeter response to π^0 and $\pi^\pm$, and the cone size used for the jets.

The corrections are piecewise quadratic functions with break-point at 100GeV. The equation and table below describe the correction.

$$f_{abs} = (P_0 + P_1 \cdot P_T + P_2 \cdot P_T^2)/100 \tag{2}$$

P_T	≤ 100.0			> 100.0		
conesize	0.4	0.7	1.0	0.4	0.7	1.0
P_0	1.37	2.09	3.29	-4.03	-1.49	-0.37
P_1	1.1946	1.227	1.2229	1.1794	1.197	1.20704
P_2	-0.0008742	-0.000839	-0.0007133	-0.0001805	-0.000182	-0.0001878

3.2.6 Level 6 Underlying Event Subtraction

Given the current luminosity of the proton anti-proton beams, it is likely that an event will have more than one interaction. This is where the extra partons from a collision interact.

Energy from particles in these extra interactions may fall in the cone of the jets from the primary interaction. This energy needs to be subtracted from the cone before analysis. This correction can be dependent on the process under study. However, it is assumed that the spectator interactions are well modeled by minimum bias events and taken care of in the level 4 correction. If additional precision is required an additional correction can be applied and is shown in the table below. This analysis does not use this correction nor level seven and eight; however, these corrections are needed for the systematic studies which will be described in chapter 4.

GeV	Cone 0.4	Cone 0.7	Cone 1.0
Run I	0.65	1.98	4.05
Run II	0.52	1.56	3.14

3.2.7 Level 7 Out-of-Cone Correction

The energy from the original parton that decays into a jet may not be entirely contained in the jet cone. Daughter particles that are part of the jet may lie outside the cone radius. This correction is intended to match the jet energy to the original parton energy by accounting for energy from particles that are Out-of-Cone. This correction is independent of detector performance and entirely relies on the parton fragmentation functions. The correction is parameterized by the following

$$P_T(OC) = A[conesize] * (1.0 - B[conesize] * e^{-C[conesize]*pt}) \tag{3}$$

where

conesize	A	B	C
0.4	22.999	0.915	0.00740
0.7	8.382	0.846	0.00728
1.0	3.227	0.832	0.00817

3.2.8 Level 8 Splash Out Correction

The final correction takes into account energy deposited in the calorimeter outside of a cone radius of R = 1.3. The correction is 0.25 GeV. This level is also no longer used. The out-of-cone definition has been expanded to take in this correction.